CLOSED-CYCLE TOTALLY CHLORINE FREE BLEACHED KRAFT PULP PRODUCTION at LOUISIANA PACIFIC'S SAMOA PULP MILL

Analysis of Business, Environmental, and Energy Issues

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About This Report

Due to the technical nature of this report, readers not familiar with pulp mills may want to read Appendix B, which describes pulp mill operations. Additionally, a number of key acronyms are frequently used throughout the report and are summarized below.

L-P	Louisiana Pacific
TCF	totally chlorine free
ECF	elemental chlorine free
PCF	processed chlorine free
CC-TCF	closed-cycle totally chlorine free
m^3/ADt	cubic meter per air-dried tonne (metric tons)

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1. Executive Summary

Overview

In 2000 Louisiana Pacific's (L-P's) 700 ton/day kraft pulp mill in Samoa, California produced totally chlorine free (TCF) bleached pulp using features of a closed-cycle process**.** This success builds on an earlier effort to eliminate chlorine bleaching, making the Samoa mill , shown in Figure 1, the first in North America to produce TCF kraft pulp. With this $7.2 million project the Samoa mill became the first site in North America to produce pulp using features of a closed-cycle TCF (CC-TCF) process.

Figure 1: Louisiana Pacific Samoa Pulp Mill

Assuming full-year operation, the CC-TCF process would provide L-P's Samoa plant with numerous benefits, including reducing:

- Bleach plant effluent by 31% to 9 m^3/ADt[1], the lowest in North America.
- Bleach plant steam use by 43%, saving $500,000/yr.
- Lime kiln bottleneck savings[2], resulting in $600,000/yr, from increased production capacity and reduced fuel use.

L-P's project team solved countless problems in implementing the CC-TCF process using cutting edge equipment, process synthesis, computer simulation and trial-and-error. The project took longer than expected, largely because of limited product demand. Although L-P's business position has limited their ability to produce TCF pulp, the TCF market is growing continuously, and U.S. paper suppliers currently import TCF pulp from Scandinavian mills.

[1] m^3/ADt = cubic meters per air-dried metric ton
[2] Bottleneck savings increases lime kiln production capacity.

This report summarizes key results that other pulp and paper mills can leverage to determine applicability of the L-P technology and approach in their mills. Further, other types of industrial plants can apply L-P's general approach to cost-effectively reduce their wastewater flow and improve process efficiency.

The report is organized in the following nine sections:

1. *Executive Summary*—describing business and technical issues for decision makers and technical staff, with the business and technical sections each intended to stand alone when used with the overview
2. *Case Study Summary*—giving a one-sheet summary intended to stand alone independently from this report
3. *Background*—summarizing reasons for pursing the project
4. *Plant Upgrade Options and Expectations* —providing an overview of benefits the project was expected to provide
5. *Construction and Startup*—describing L-P's experiences in installing and starting new equipment
6. *Results* —showing the impact on the company's bottom line
7. *Market Issues*—summarizing recent industry activities and L-P business considerations for pursing TCF market opportunities
8. *Potential California Applicability*—briefly describing the market potential for other California installations
9. *Appendices* —including a pulp-production overview and a detailed listing of potential California CC-TCF applications

Summary of Business Issues

Project Cost and Financing

The project was completed at a net cost to the company of $6.6 million, after receiving $650,000 in grants from the U.S. Department of Energy (DOE) NICE^3 program[3] and the California EPA. L-P funded the project with internal funds. The final project cost was within the initial budget.

Design and Construction

L-P assembled a team of technical experts from among on-site staff, industry and university researchers, and equipment vendors to develop the CC-TCF process. The team applied new equipment, process synthesis, computer simulation plus trial-and-error to implement the project.

Design and construction was slated to require 18 months from start to finish, but various issues delayed the project. One issue was implementation problems, as could be expected

[3] NICE^3 = National Industrial Competitiveness through Energy, Environment, and Economics

when establishing North America's first closed cycle process. Causing more delay, however, was the lack of demand for bleached pulp. Since the plant's biggest selling product is currently unbleached pulp, the project team had to wait until TCF pulp orders allowed them to implement various phases of the process.

Evolutionary, Low-Budget Process Development

Another reason this project required more time to complete was its evolutionary character. No magic formulae or off-the-shelf equipment exist to accomplish the conversion of an existing pulp mill to CC-TCF. The project team's methodology was to apply a step-by-step generation of ideas, mill testing and follow-up evaluation using many process engineering tools—from common sense to basic analysis to computer simulation.

An added restriction driving the project approach was the very limited capital availability. Only one major piece of equipment has been purchased to-date—the Ahlstrom X-Filter™, at $6.6 million. All remaining work has been completed for about $650,000.

Projected Versus Actual Operation

In the CC-TCF run in January 2000, the L-P Samoa Mill produced over 5000 tons of high-quality, chlorine-free pulp at an improved production rate. Chemical costs were high but the bleaching modernization project described later in this summary is expected to bring costs in line with pre-TCF production. Table 1 summarizes the economic impacts to-date from implementing the CC-TCF process improvements.

Table 1: Economic Impact To-Date From CC-TCF Improvements

Plant Area	*Change*	*Value*	*Source*
Bleach plant steam	43% savings	$500,000 per year	Hot water recycling
Lime-kiln capacity	2% increase	$600,000 per year	Improved production capacity

Future Considerations

For mills considering CC-TCF and/or TCF operation, L-P cautions plant managers to carefully evaluate their process flows to thoroughly understand how to best design a new system. As they learned, implementing CC-TCF requires a plant-specific approach—a number of general concepts can be applied, but this process improvement is not available with a "skid-mounted" equipment solution that can be easily installed in any other pulp plant. Other important lessons include:

- Staff dedication, persistence, and creativity are key to such a project. Plant personnel faced countless challenges to ensure not only proper operation, but also superior performance.

- Pollution prevention by modifying plant processes is a more cost-effective approach than "end-of-the-pipe" wastewater treatment. L-P has reduced wastewater flows, fresh water flows, and reclaimed chemicals and waste heat formerly lost with the waste flows. Therefore, pollution prevention approaches cut operating costs.

- Constantly re-evaluate the plant processes to seek improvement. After successfully demonstrating the CC-TCF process in early 2000, L-P staff immediately identified an approach to cut bleach plant wastewater flow by an additional 15-25%. This recovers heat as well as residual bleach chemical (hydrogen peroxide).

Market Issues

On April 15, 1998 the EPA promulgated a combined air and water “cluster rule” for the pulp and paper industry to reduce toxic pollutant releases. In effect, pulp/paper mills are required to transition from bleaching with elemental chlorine to bleaching with either chlorine dioxide (elemental chlorine free, ECF) or a totally chlorine free (TCF) approach.

Early U.S. pulp/paper industry research showed that adopting the ECF process required lower capital cost than adopting a TCF approach and thus promoted the ECF alternative. Therefore, U.S. industries have been pursuing ECF process upgrades to meet cluster rule requirements. U.S. pulp/paper mills are in various stages in meeting the cluster rule requirements. By August 1999 a survey[4] showed 70.4% of the total 1999 U.S. capacity of 33.36 million tons had been converted to ECF production.

In addition to discharging zero chlorine products, an additional TCF benefit is the opportunity to implement the closed-cycle option, which reduces fresh water usage and cuts bleach plant wastewater discharge to near zero. The conventional ECF approach offers wastewater reduction of only about 50% compared to chlorine-based bleaching.

As the public has become more aware of the potential environmental damage cuased by chlorine and chlorine-using processes, market interest in chlorine-free products has grown and a number of governmental bodies are requiring chlorine free paper. In fact, one paper-supplier is no longer accepting orders for chlorine-free products because their 80,000 ton/year capacity is already allocated. Since L-P is the only U.S. TCF pulp supplier and it has produced limited quantities of TCF products, nearly all TCF pulp is imported from Scandinavia.

L-P’s Next Step—CC-TCF Process Upgrades

To improve the CC-TCF process efficiency, L-P has designed and obtained permits to install a upgrade expected to cost about $6 million, but valued at about $15 million since L-P will purchase used equipment. L-P's analysis shows that this upgrade will allow the plant to produce TCF pulp with similar manufacturing costs as compared to their pre-TCF operation.

[4] *Pulp & Paper*, September 1999, pp 73-4.

Summary of Technical Issues

TCF Operation Facilitates Closed-Cycle Operation

L-P implemented the CC-TCF process relatively inexpensively only because it had already adopted the TCF process. Since January 1994, the Samoa mill has been the only North American kraft pulp mill to produce bleached kraft pulp without the use of chlorine or chlorine-containing compounds on a permanent basis. The TCF bleaching process employed at the Samoa mill uses hydrogen peroxide and oxygen as alternative bleaching agents to the conventional bleaching chemicals, chlorine and chlorine dioxide.

Implementing the TCF process cost L-P about $4 million before the CC-TCF project began. Other pulp plants adopting the TCF process will incur higher costs if they do not have an oxygen delignification unit, costing about $7 million.

Adopting the TCF process gave L-P numerous benefits, including:

- Cut bleach-plant effluent by 71%, to 13 m^3/ADt[5]
- Cut bleach-plant water usage by 50%, to 22 m^3/ADt
- Cut mill process water usage by 31%, to 52 m^3/ADt
- Eliminated discharge of chlorine compounds into the ocean

Closed-Cycle Issues and Impacts

Coupled with innovative process changes, the Samoa mill required the addition of the following technologies to implement closed-cycle operation:

- Advanced green liquor filtration
- Extended digester cooking
- Modified filtrate-recycle configuration

The $6.6 million green liquor filtration unit (Ahlstrom X-Filter™), a unique piece of equipment and the only one of its kind in North America, was particularly critical since it allowed recycling of wastewater streams that the plant was otherwise forced to discharge into the ocean.

Figure 2 gives an overview of plant operations and Table 2 summarizes CC-TCF system performance.

[5] m^3/ADt = cubic meters per air-dried metric ton

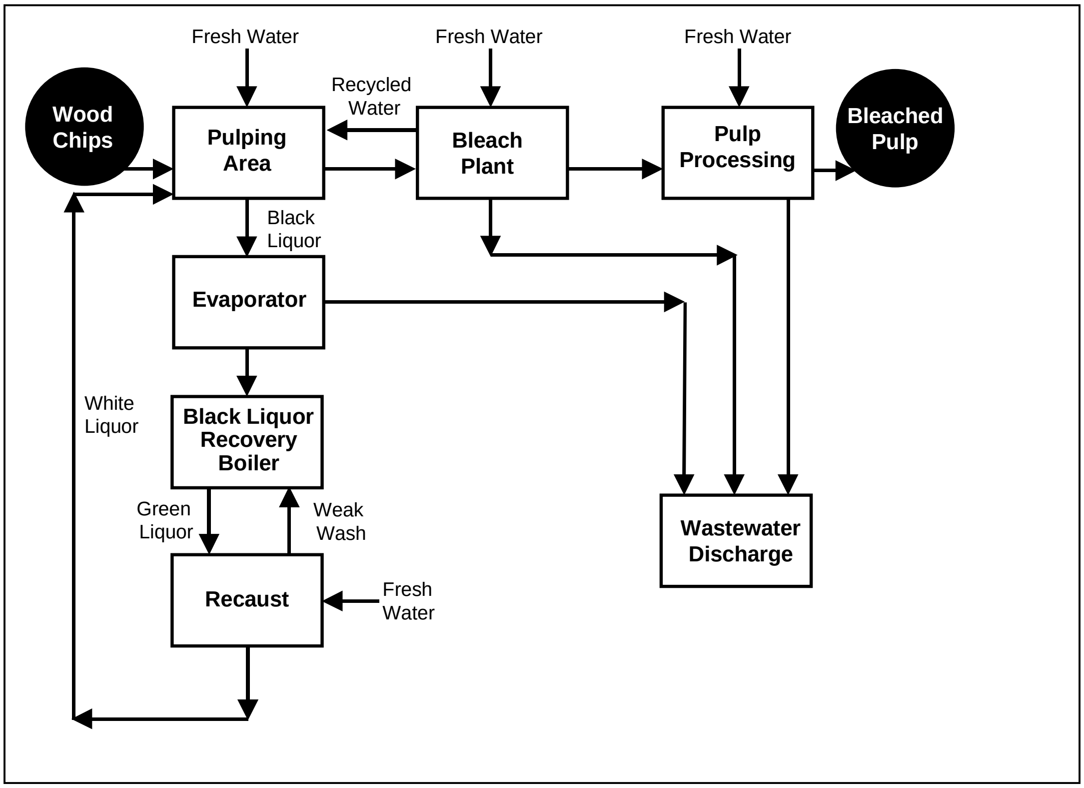

Figure 2: Overview of Pulp Mill Processes

Table 2: CC-TCF System Performance

Characteristic	*Units*	*TCF 1995*	*CC-TCF 2000*	*CC-TCF improvement vs TCF*
Pulp production	ADt/day	532	545	2%
Mill process water use*	m^3/ADt	52	42	19%
Mill effluent	m^3/ADt	113	100	12%
Bleach plant water use	m^3/ADt	22	18	18%
Bleach plant effluent	m^3/ADt	13	9	31%
Bleach plant steam	GJ/ADt	2.47	1.42	43%
Mill electricity use**	kWh/ADt	909	909	0%

* Excludes 8.6 mgd of cooling water and non-contact process water.
** 90-95% from on-site cogeneration plant.

Planned CC-TCF Improvements

To improve the CC-TCF process efficiency, increasing production capacity by 20% and bringing it back to pre-TCF levels as shown in Table 11 later in the report, L-P has designed and obtained permits to install a $6 million upgrade. The project will include completing the following three key steps:

1. Retrofitting the oxygen delignification unit to have two stages

2. Installing two new pulp-wash presses
3. Installing a pressurized peroxide bleaching system

Table 3: Expected Impacts of Closed-Cycle TCF Process Improvements

Characteristic	*Units*	*CC-TCF 2000*	*CC-TCF 2001 (est.)*	*CC TCF 2001 improvement vs. CC-TCF 2000*
Pulp production	ADt/day	545	636	17%
Mill process water use*	m^3/ADt	42	22	48%
Mill effluent	m^3/ADt	100	71	29%
Bleach plant water use	m^3/ADt	18	0.7	96%
Bleach plant effluent	m^3/ADt	9	7.6	16%
Bleach plant steam	GJ/ADt	1.42	1.42	0%
Mill electricity use	kWh/ADt	909	916	-1%

* Excludes 8.6 mgd of cooling water and non-contact process water.

Summary

Designing, installing, and operating the CC-TCF process has been a challenging but rewarding experience for L-P staff. The Samoa mill is well positioned to pursue new market opportunities as the demand for TCF pulp and paper products increases.

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2. Case Study Summary

The following page is a one-sheet summary that can be distributed independent of this report. It is designed for widespread distribution to summarize key results from installing CC-TCF process modifications.

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Summary

Facing a lawsuit to clean up effluent flow, Louisiana-Pacific's (L-P) 700 ton/day kraft pulp mill in Samoa, California, implemented a totally chlorine-free (TCF) bleaching process in the 1990s. In 2000, the mill completed a $7.2 million closed-cycle TCF (CC-TCF) upgrade to increase production and cut costs.

The CC-TCF process has demonstrated the ability to cut annual operating costs $1.1 million, while reducing bleach plant effluent 31% and mill process water use 19%.

Building on this success, L-P plans to implement an additional $6 million CC-TCF upgrade that will enable the plant to produce pulp competitively with those using other bleaching processes. The upgrade will nearly eliminate bleach plant effluent, while cutting mill water use by 48% and increasing plant capacity.

Looking beyond pulp mills, other types of industrial facilities can also cut operating costs and reduce environmental impacts by applying L-P's process improvement concepts to their own plants.

CLOSED-CYCLE OPERATION TO CUT COST $1.1 MILLION/YEAR

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INDUSTRIAL

Closed Cycle to Cut Pulp Mill Operating Cost and Water Use

Background

The pulp and paper industry is the fourth largest consumer of fossil fuels in the United States and the single largest consumer of process water. However, the potential for recycling bleaching wastewater has been limited because of the water's corrosivity.

TCF Bleaching Eliminates Dioxins

Having exhausted many of the gains achievable through end-of-pipe pollution control, the industry is innovating process changes to improve wastewater quality. One approach uses no chlorine-containing compounds and is labeled totally chlorine-free (TCF) bleaching.

Additional approaches include the recycle and recovery of all pulping and bleaching process wastewaters-termed "closed cycle." The pulp and paper industry is rapidly developing closed-cycle technologies.

Closed-Cycle Installation Cuts Costs

In 2000, L-P's kraft pulp mill in Samoa, California, produced TCF bleached pulp using features of a closed-cycle process. This success builds on L-P's earlier effort to eliminate chlorine bleaching and harmful dioxin effluents, making it the first mill in North America to produce TCF pulp.

L-P implemented the CC-TCF process to improve plant performance, enabling them to produce a competitively priced TCF product. The upgrade included many steps, the most significant being:

1. Installing an "X-Filter" for advanced green liquor filtration
2. Modifying the filtrate recycling process
3. Extending the digester cooking process

With this $7.2 million project, the Samoa plant became the first site in the world to produce pulp using features of a CC-TCF process. With full-year CC-TCF operation this upgrade would cut operating costs by about $1.1 million/year as shown in Table 1.

Table 1: Savings from CC-TCF Improvements

Plant Area	Benefit	Value	Source
Bleach plant steam use	43% savings	$500,000	Heat recovery water recycling
Lime-kiln debottlenecking	2% capacity increase	$600,000	Lower feed moisture

Process Changes Cut Pollution and Water Use

The key to L-P's success has been the company's ability to identify water reuse and treatment opportunities *within* the plant processes, rather than just "end-of-the-pipe" effluent treatment. Such an approach has proven not only technically superior, but also very cost effective.

One piece of equipment—the Ahlstrom X-Filter—required 91% of the total CC-TCF project cost. This critical, unique unit allows the plant to recycle wastewater that would otherwise be discharged to the ocean. Project personnel implemented all other improvements at a cost of only $650,000.

L-P's CC-TCF demonstration confirmed that the process delivers high-quality pulp. However, the process also reduced production capacity. Therefore, L-P's planned $6 million upgrade is designed to recoup that lost capacity and make the process cost-competitive with standard bleaching techniques by further "closing" plant process flows. Closing plant flows also reduces operating costs by cutting chemical and steam usage.

The enhanced CC-TCF process will deliver the performance improvements noted in Table 2, as compared to the current CC-TCF baseline established in 2000. In particular, bleach plant effluent will be nearly eliminated.

Table 2: Additional Performance Improvements from CC-TCF Upgrade

Measure	Improvement	New Level
Production capacity	up 17%	6.36 ADt/day*
Bleach plant effluent	cut 96%	0.7 m^3/ADt
Mill process water use	cut 48%	22 m^3/ADt**
Mill effluent	cut 29%	71 m^3/ADt

* Within 1% of the pre-TCF capacity
** Includes 51 m^3/ADt of water for cooling and non-contact processes

3. Background

Pulp/Paper Industry Perspective

The United States pulp and paper industry is the fourth largest consumer of fossil fuels in the country and the single largest consumer of process water. Each year, the industry consumes over three quads of energy and discharges approximately 1.5 trillion gallons of wastewater.

As expressed in the Clean Water Act, “it is the national goal that the discharge of pollutants into the navigable waters be eliminated.” The kraft pulp industry has yet to develop a pulping and bleaching technology that can achieve this goal.

The wastewater of greatest concern from a pollution standpoint is that generated during the pulp bleaching process. The use of chlorine compounds for bleaching results in discharge of priority pollutants such as chlorinated dioxins. Other components of wastewater discharge include biochemical and chemical oxygen demand (BOD and COD, respectively), color, toxicity, and various dissolved organics. Approximately 330 billion gallons of wastewater are discharged from pulp bleaching operations per year.

The potential for recycle of bleaching wastewater has been limited because of the corrosivity of the residual chlorine compounds contained in the wastewater. As a result, pulp mills discharge bleach plant wastewater, releasing contaminants, residual bleaching chemicals, and recoverable heat-energy to the environment.

Having exhausted many of the gains achievable through end-of-pipe pollution control, the pulp and paper industry is innovating process changes to improve wastewater quality. The most promising pollution prevention technologies gaining worldwide acceptance from both industry and regulators are:

- Find substitutes for elemental chlorine and hypochlorite bleaching agents
- Reduce or eliminate bleach plant effluent

Two bleaching technologies are evolving to achieve these objectives. One uses no chlorine-containing compounds and is labeled TCF bleaching (totally chlorine free). The other uses chlorine dioxide, and is labeled ECF bleaching (elemental chlorine free). These advancements in alternative bleaching technologies (especially TCF) have made recovery of energy, process water and bleaching chemicals a feasible approach to energy conservation, water conservation and pollution prevention. The recycle and recovery of pulping and bleaching process wastewaters is termed “closed cycle.” The pulp and paper industry is developing closed-cycle technologies, but in North America little progress has been achieved before L-P's project.

Louisiana Pacific Pulp Plant Overview

Louisiana-Pacific Corporation (L-P) owns and operates a bleached kraft pulp mill in Samoa California. Constructed in 1964, the plant is located on the Samoa Peninsula in Humboldt County, an environmentally sensitive area on the northern California coast. The Samoa pulp mill, partially shown in Figure 3, has a capacity of approximately 700 tons of bleached or unbleached kraft market pulp per day. The pulp is produced from waste wood chips generated by local sawmills. An overview of the process is shown in Figure 4. A detailed description of the pulp production process, along with a process schematic, is given in Appendix B: Pulp-Production Overview.

Figure 3: Samoa Pulp Mill Digestor

Pulp mills throughout the nation and especially in California have experienced significant regulatory and public pressure for continual environmental improvement. The pressure on Samoa mill peaked in 1989 with litigation by the Surfrider Foundation and the EPA over the quality of its wastewater discharges.

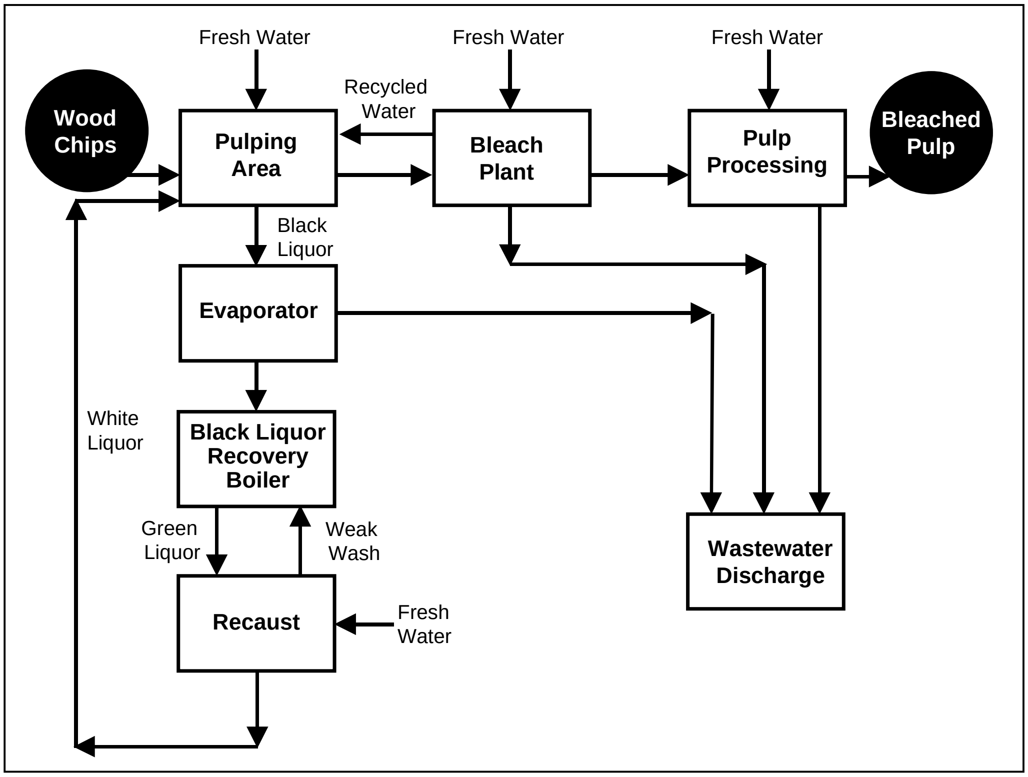

Figure 4: Samoa Mill Process Overview

Origins of Change

The 1989 Surfrider lawsuit forced L-P to develop a long-term plan for environmental improvement. Conventional secondary wastewater treatment, applied as a national prescription for pulp mills by EPA, was not considered appropriate given the unique circumstances of the Samoa mill. EPA determined that the environmental impacts of secondary treatment, including air emissions, solid waste generation, and energy consumption, exceeded the projected benefits by an unreasonable amount. Additionally, the mill is located in coastal dune habitat containing endangered plant species. Disturbing this land to build a large water treatment plant would involve further environmental trade-offs.

In 1990 L-P proposed to eliminate the use of chlorine and recycle wastewater as part of the agreement settling the litigation. At the time, only a few Scandinavian mills were working with TCF processes. Thus, the TCF production process was not well known, the environmental benefits were thought to be substantial, but not well documented, and the consumer market for TCF pulp was not yet established. L-P took a calculated business risk to pursue the TCF process.

L-P could consider recycling wastewater and adopting the TCF process because a plant modernization project in 1989 laid the groundwork. The primary upgrades included installing an oxygen delignification unit, at a cost of about $7 million, and building a new recovery boiler, which cost about $60 million. The additional changes to implement the TCF process were estimated to cost $4 million. These changes included removal of all chlorine and chlorine dioxide facilities, adding hydrogen peroxide storage and distribution piping, and a steam stripper for condensates.

In January 1994, the Samoa mill became the only North American kraft pulp mill to produce bleached pulp without the use of chlorine or chlorine containing compounds on a permanent basis. The TCF bleaching process employed at the Samoa mill uses hydrogen peroxide and oxygen as alternative bleaching agents to the conventional bleaching chemicals, chlorine and chlorine dioxide. When producing unbleached pulp, the mill does not use any bleaching chemicals.

At this time the Samoa mill remains the only facility in North America using the TCF process to produce bleached kraft pulp. However, Scandinavian mills have led the world's development of TCF pulp production, partly in response to European demands for TCF paper, particularly from Germany and its Green Party. These market forces have not had a significant influence on the world pulp market.

Implementing the TCF process cost L-P about $4 million. Other plants adopting the TCF process could incur higher costs if they do not have an oxygen delignification unit, used in only about 20% of all U.S. pulp mills.

Impacts of the TCF Process

The Samoa mill produces TCF pulp by bleaching with hydrogen peroxide and oxygen. The non-corrosive chemistry of these chemicals and the similarity of pH and temperature conditions between bleaching stages make recycling TCF bleaching wastewater simpler than if chlorine was used. Using the oxygen delignification unit, along with recovering additional chemicals in the wastewater stream and recycling wastewater, has produced numerous benefits, as summarized below and detailed in **Error! Reference source not found.**.

- Cut bleach-plant effluent by 71%, from 45 to 13 m^3/ADt
- Cut bleach-plant water usage by 50%, from 44 to 22 m^3/ADt
- Cut mill process water usage by 31%, from 75 to 52 m^3/ADt
- Reduced bleach-plant steam usage by 17%, to 2.47 GJ/ADt
- Improved the wastewater clarity, as shown in Figure 5
- Eliminated discharge of chlorinated organics into the ocean, cutting risks to surfers and sea life
- Reduced plant odor, with average monthly AQMD odor complaints dropping from 116 in 1990 to 48 in 1995

Pulp brightness has suffered somewhat due to the TCF process. However, it has improved steadily as plant personnel have gained experience with the TCF process and made minor upgrades. In January 2000 L-P successfully produced 5000 tons of TCF pulp with brightness levels in the 87–89 range. Table 4 summarizes key product characteristics.

Table 4: TCF Pulp Quality Improvement

Characteristic	*Chlorinated Baseline Pre-1993*	*TCF Softwood*		
		1993	*1994*	*2000*
Fold	1500	725	1000	1000
Breaking Strength	9,500	8,840	9,400	8300
Burst	75	62	68	57
Tear	120	99	130	117
Viscosity	65	40	60	na
Brightness	90+	75-80	85+	87+

However, along with reduced water usage, environmental benefits, and steadily improving product quality, the TCF process reduced plant production 16%, to 532 ADt, but reducing steam and water usage per ton of product as shown in **Error! Reference source not found.**.

Table 5: TCF Impacts on Plant Performance

Characteristic	*Units*	*Pre-TCF 1993*	*TCF 1995*	*TCF Improvement*
Pulp production	ADt/day	630	532	-16%
Mill process water use*	m^3/ADt	75	52	31%
Mill effluent	m^3/ADt	128	113	12%
Bleach plant water use	m^3/ADt	44	22	50%
Bleach plant effluent	m^3/ADt	45	13	71%
Bleach plant steam	GJ/Adt**	2.97	2.47	17%
Mill electricity use***	kWh/Adt	861	909	-6%

* Excludes 8.6 mgd of cooling water and non-contact process water.
** GJ = giga joules.
*** 90-95% from on-site cogeneration plant.

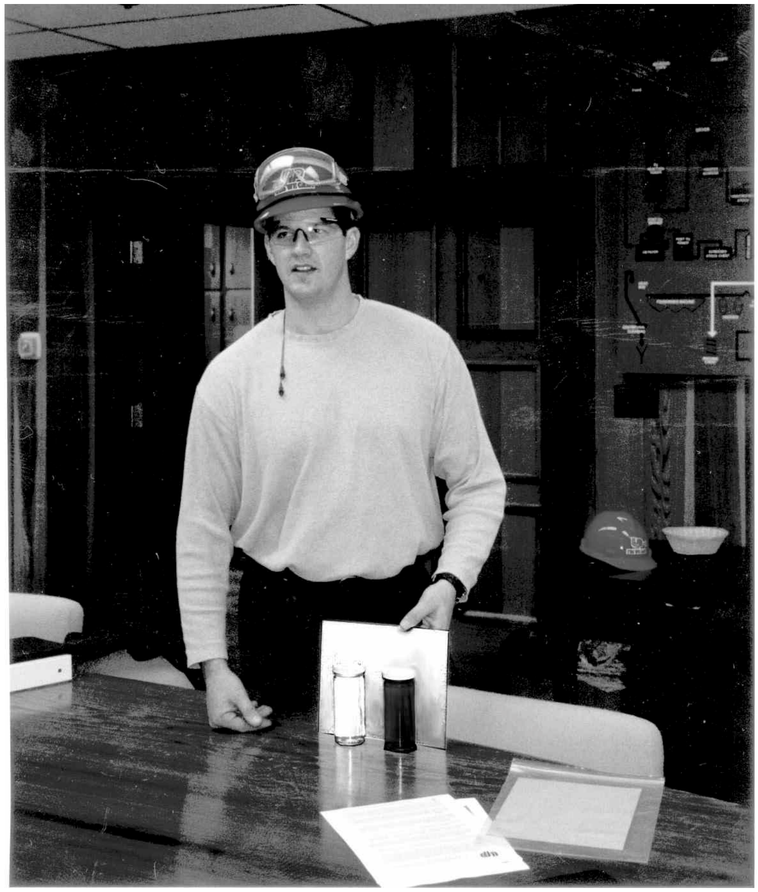

Figure 5: Plant Effluent After (left) and Before (right) TCF Process Implementation

TCF Process Offers Closed-Cycle Opportunity

As the plant personnel increased their expertise in the TCF process, they realized a need to increase TCF cost-efficiency as well as a desire to cut wastewater discharge and continue reducing environmental impacts. Further, L-P wanted to promote the environmental benefits of TCF pulp and gain a market advantage over competitors who did not have the established plant infrastructure to adopt TCF so easily. In 1995 L-P initiated a project to implement a closed cycle TCF (CC-TCF) process with full bleach recycle (FBR).

4. Closed-Cycle TCF Upgrade Plans and Expectations

Project Approach

TCF bleaching characteristics provide an opportunity to close the bleaching process cycle and reuse nearly all the water used in the bleaching process. Thus TCF offers closed-cycle benefits over chlorine-based processes which do not lend themselves well to wastewater recycling due to the corrosive chlorine chemistry involved. However, adopting a closed cycle poses technical challenges, including:

- Mineral buildup within the system
- Spills and overflow during start-up, normal operation, and shutdown.
- Hydraulic control of internal process waste-water flows
- Control of transition metals that impact peroxide efficiency.

L-P assembled a team of technical experts representing vendors, engineers, and industry and university researchers to assist L-P in developing a closed cycle operation. Participants included L-P, H.A. Simons Ltd., University of Idaho, California Energy Commission, Battelle, and Forsgren Associates Inc.

The project team used existing mill data and computer simulations to evaluate alternative system configurations. Optimal alternatives were testing using full-scale mill trials. The design process included new equipment, process synthesis, computer simulation, and trial-and-error to minimize capital cost.

L-P's process already included two key technologies required for CC-TCF operation—oxygen delignification and a high efficiency recovery boiler. Coupled with innovative process changes, adding the following technologies was expected to enable closed-cycle operation:

- Advanced green liquor filtration
- Extended digester cooking
- Modified filtrate-recycle configuration

Expected Performance

The project goal was to commercialize the first kraft pulp mill in the world with a zero-discharge bleach plant, while economically producing strong, bright, bleached pulp. With the plant upgrades completed in the late 1980s and early 1990s, the bleach plant effluent dropped about 80%. With the closed cycle plant modifications the plant was expected to have nearly zero discharge. Additionally, the CC-TCF process change was expected to not have any labor impacts on plant operation.

Budget, Investment Criteria, and Funding

The project's initial budget was $7.25 million, with L-P's net cost reduced to $6.6 million with the grants summarized in Table 6. The grants provided not only 9% of the project funding, but more importantly seed money to begin the project. L-P likely would not have begun the project without the supplemental funding. L-P's only expense was to purchase the Ahlstrom X-Filter; all other expenses were covered by the outside funding.

Table 6: Project Funding Partners

$400,000	U.S. Department of Energy's NICE[3] program (National Industrial Competitiveness through Energy, Environment, and Economics)
$250,000	California EPA (defense conversion monies)
$650,000	Total

Expected Timeline

L-P's expected timeline is summarized in Table 7. The project was expected to require 18 months after receiving DOE's award.

Table 7: Expected Project Timeline

Milestone	*Months from DOE Award*
1. Recycle and recover 100% of peroxide stage filtrates	6
2. Recycle and recover 100% of the chelation (metals purge) stage filtrate	18
a. Install and test split showers on shelation stage and post oxygen washers	5
b. Conduct mill tests of fiber line recycle and use of filtrate in liquor preparation	13
c. Complete engineering design and cost estimates to compare evaporation and recaustisizing upgrade	13
d. Install and evaluate full-scale green liquor dregs removal and dewatering system	17
3. Design and implement spill prevention, energy management, metals management, and environmental management process control system; subtasks noted below	
a. Design logic and system instrumentation	6
b. Install hardware	9
c. Install and evaluate software	11
Project complete	18

5. Construction and Startup

Overview

In general, design and construction went well but plant start-up has been hampered by the nature of creating a new process with a trial-and-error approach. However, plant personnel developed countless solutions and have nearly achieved complete closed-cycle operation.

Design, Construction and Budget Issues

The design process and construction has gone as smoothly as can be expected with such a revolutionary project. However, the process has taken longer than expected since the project's design and construction has been, in effect, a trial-and-error process. Plant engineers and researchers have made numerous small changes since the project began. Another cause for delay has been lack of demand for the TCF product, thus the plant has produced very little bleached pulp.

In effect, developing the CC-TCF process has been an evolutionary development, occurring almost continuously since L-P adopted TCF bleaching. As each step is completed, the project team identifies and implements additional process improvements.

Startup Issues

After starting the project, L-P reached its first major project milestone in May 1995 by demonstrating 100% recycle of all alkaline peroxide bleaching wastewaters. Non-process elements, such as potassium, chloride, calcium and magnesium built up within a closed cycle mill and interfered with production processes. To handle this build-up, in May 1996 L-P installed an advanced green liquor filtration system, the Ahlstrom X-Filter, to increase the mill's non-process element purge capability. L-P also purged recovery boiler precipitator dust to maintain non-process elements in the liquor cycle at acceptable levels.

Timeline

After DOE approved the NICE[3] award, L-P's first successful closed-cycle TCF product run was completed in January of 2000 and the final process modifications were completed in late 2000. As noted earlier, the closed-cycle project required much longer than expected because of the project's customized nature and the lack of TCF product demand.

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6. Results

Summary

L-P's CC-TCF process has been a technical success, with steam and gas costs cut by $700,000/year, bleach plant effluent down by 31%, and mill process water down 19%. The project was greatly delayed by market issues and plant engineers solved numerous technical hurdles in designing the world's first bleach plant that operates with a nearly closed-cycle.

Samoa mill personnel have identified approximately $6 million of additional plant improvements necessary to make the closed-cycle TCF process competitive with chlorine-based bleaching plants. However, the lack of demand for the TCF product has given L-P limited opportunities produce TCF pulp.

The Bottom Line

The CC-TCF process as installed delivered the key benefit L-P expected to achieve—making the TCF process more competitive with other bleaching technologies. Further, the ground-breaking work of the last several years has identified the final hurdles to nearly eliminating the bleach plant's effluent.

The project likely would not have been implemented without the DOE NICE[3] grant, a catalyst for L-P to pursue the upgrade. A number of benefits are summarized in Table 8 below, assuming a full year of CC-TCF operation.

Table 9 describes additional plant performance characteristics while Table 10 details CC-TCF impact on product quality. Additionally, Figure 7 and Figure 8 summarize several other environmental benefits.

Table 8: Summary of CC-TCF Benefits

Operating Cost Impacts	
Bleach plant steam use	Down by 43%, totaling $500,000/year
Lime-kiln gas usage	Cut 5%, totaling $200,000/year, from improved production capacity
Labor	No additional labor required, as expected
Water/Wastewater	
Bleach plant effluent	Down by 31%, to 9 m^3/adt, the lowest in North America
Mill process water use	Down by 19%, to 42 m^3/adt

Table 9: Closed-Cycle TCF Pulp Plant Performance

Characteristic	*Units*	*TCF 1995*	*CC-TCF 2000*	*CC-TCF improvement vs TCF*
Pulp production	ADt/day	532	545	2%
Mill process water use*	m^3/ADt	52	42	19%
Mill effluent	m^3/ADt	113	100	12%
Bleach plant water use	m^3/ADt	22	18	18%
Bleach plant effluent	m^3/ADt	13	9	31%
Bleach plant steam	GJ/ADt	2.47	1.42	43%
Mill electricity use**	kWh/ADt	909	909	0%

* Excludes 8.6 mgd of cooling water and non-contact process water.
** 90-95% from on-site cogeneration plant.

Table 10: Closed-Cycle TCF Impacts on Product Quality

Characteristic	*Chlorinated Baseline Pre-1993*	*TCF 1994*	*CC-TCF 2000*
Fold	1500	1000	1000
Breaking Strength	9,500	9,400	8300
Burst	75	68	57
Tear	120	130	117
Viscosity	65	60	na
Brightness	90+	85+	87+

The project cost was nearly identical to the projected $7.25 million. Funding from DOE's NICE[3] program was critical for purchasing the hydrogen peroxide bleaching tower. L-P's key purchase was the $6.6 million X-Filter on the green liquor flow line, the only such filter in North America, as shown in Figure 6.

Figure 6: Ahlstrom X-Filter

Environmental Impacts

In addition to the reduced water, wastewater, and energy benefits noted earlier, the CC-TCF process improved the wastewater's color and reduced loading from biological oxygen demand (BOD) and chemical oxygen demand (COD). Figure 7 and Figure 8 show the available data demonstrating color and BOD/COD improvements.

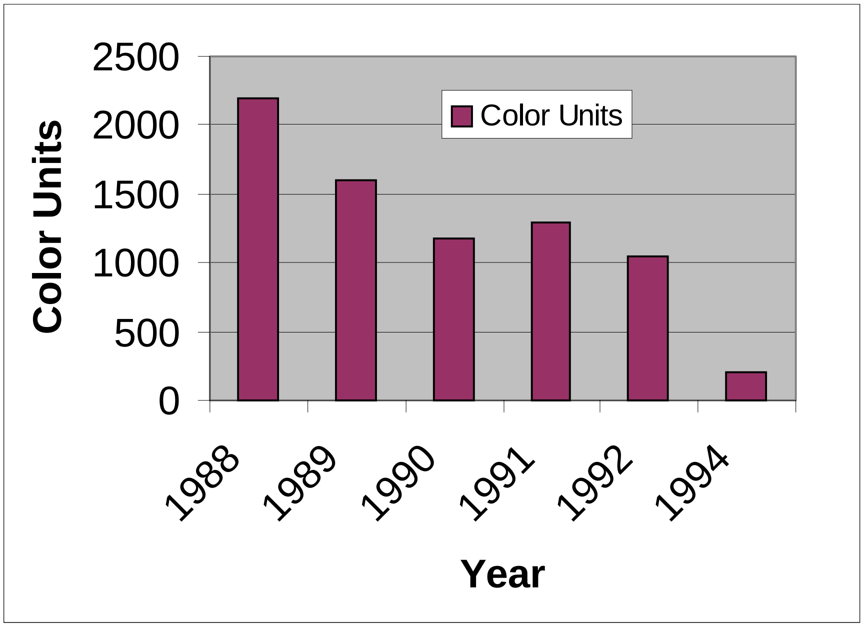

Figure 7: Effluent Color Improvement

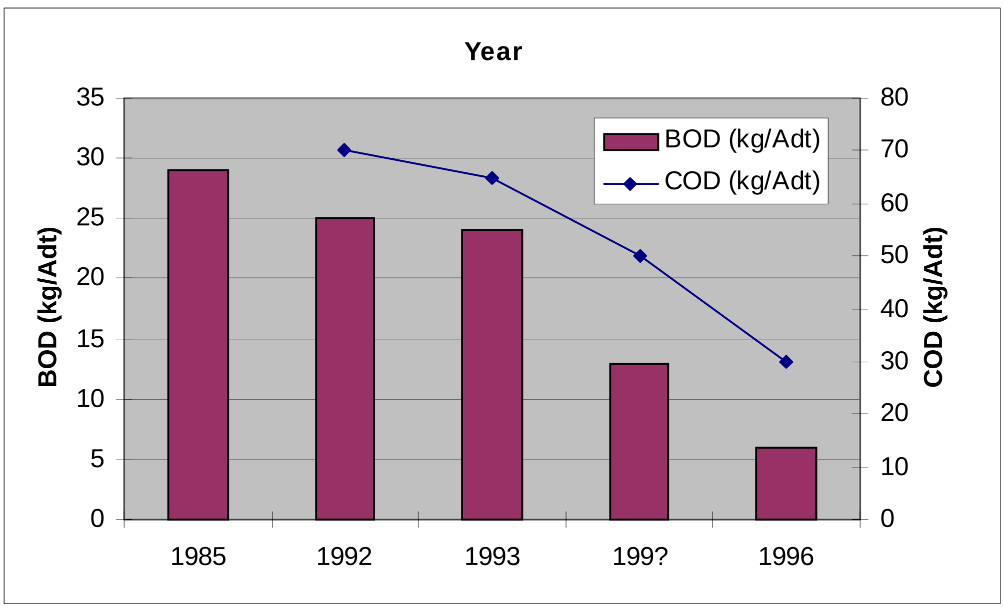

Figure 8: BOD and COD Improvement

Suggestions for Future Installations

L-P engineers, plant operators, and research staff have learned many lessons in implementing their closed-cycle TCF process, as summarized below:

- Staff dedication, persistence, and creativity are key to such a project. No other pulp plant in the world has progressed as far toward a closed-cycle bleach plant until L-P undertook the CC-TCF upgrade. Plant personnel faced countless challenges to ensure not only proper operation, but also superior performance.
- Pollution prevention by modifying plant processes is a more cost-effective approach than “end-of-the-pipe” wastewater treatment. L-P has reduced wastewater flows, fresh water flows, and reclaimed chemicals and waste heat formerly lost with the waste flows. Therefore, pollution prevention approaches cut operating costs.
- Learn from others. Scandinavian pulp plants pioneered TCF pulp processes and L-P learned a lot from them.
- Constantly re-evaluate the plant processes to seek improvement. After successfully demonstrating the CC-TCF process in early 2000, L-P staff immediately identified an approach to cut plant wastewater flow by an additional 38% and simultaneously recover heat from a 100°F wastewater flow.
- Consider solid waste issues. L-P generates 25 tons/day of waste from the X-Filter. This material, in effect the wood chips’ mineral content, could be used as a lime replacement in agricultural applications, but is currently used as cover material at a local landfill.

7. Market Issues

Other CC-TCF Applications

To L-P's knowledge, no other CC-TCF processes have been designed or installed in pulp and/or paper mills in the world. Scandinavian mills are leading the world's development of the TCF process but none of their plants have yet achieved a closed-cycle bleach plant.

U.S. EPA Cluster Rule

In late 1997 the EPA issued Phase I of a combined air and water "cluster rule" for the pulp and paper industry to reduce toxic pollutant releases. The minimum standards cut toxic air pollutant releases by almost 60% and eliminate 96% of all dioxin and furan discharged into rivers and other surface waters. The rule also provides individual mills with incentives to adopt advanced pollution control technologies that will lead to further reductions in toxic pollutant discharges beyond the water discharge limits set in the rule. Phases II and III are expected in the next year or two.

EPA established the cluster rule after lengthy discussions with industry organizations to identify appropriate technologies and pollutant discharge levels. In effect, pulp/paper mills are required to transition from bleaching with elemental chlorine to bleaching with either chlorine dioxide (elemental chlorine free, ECF) or a total chlorine free (TCF) approach. EPA staff spent about two weeks documenting L-P's TCF process performance and integrated their research into the cluster rule's development.

The rule regulates toxic air discharges in 155 of the nation's 565 pulp, paper, and paperboard mills in the United States, and it regulates toxic water discharges in 96 of the 155 mills. To meet cluster rule requirements, early EPA estimates placed the capital investment for all U.S. pulp/paper mills at about $1.8 billion, with the American Forest & Paper Association (AP&FAP) estimating $2.6 billion.

Pulp/paper mills across the country are at various stages in meeting the cluster rule requirements. By August 1999 a survey showed 70.4% of the total 1999 U.S. capacity of 33.36 million tons had been converted to ECF production, with 26.1% of capacity not yet converted and 3.5% to be permanently shut down between 1999 and 2001. Four of the nine largest kraft pulp producers are already 100% converted to ECF production capability.[6]

L-P's aggressive approach to addressing environmental issues with the CC-TCF approach has provided early compliance. For example, the schedule requires steam-stripper installation by 2001, but L-P installed one in the mid-1990s. L-P's combination of activities puts L-P in compliance with all cluster rule regulations through 2006.

[6] *Pulp & Paper*, September 1999, pp 73-4.

ECF vs. TCF Approaches to Meet Cluster Rule Requirements

Early in the cluster rule's development, U.S. pulp/paper industry research showed that adopting the ECF process required lower capital cost than adopting a TCF approach and thus promoted the ECF alternative. Therefore, U.S. industries have been pursuing ECF process upgrades to meet cluster rule requirements.

However, a recent Environment Canada study showed that converting to TCF had lower capital cost than converting to ECF, depending on plant configurations. Additionally, the American Forest Products Association recently reduced their cost estimate to adopt ECF processes. Further, Scandinavian mills are competitively upgrading to the TCF approach.[7] Thus the ECF vs. TCF cost difference is open to debate.

In addition to discharging zero chlorine products, an additional TCF benefit is the opportunity to implement the CC option, which reduces fresh water usage and offers opportunities to nearly eliminate bleach plant wastewater discharge. The ECF approach offers wastewater reduction of only about 50% compared to chlorine-based bleaching.

Interestingly, although 70.4% of U.S. production capacity is ECF-capable, many mills continue using chlorine because operating costs are lower and the cluster rule does not require ECF operation until 2001. U.S. TCF production is negligible, at about 200,000 tons/year since 1993.[8]

While the cost to meet cluster rule requirements varies with each mill's existing configuration, some plants with outdated equipment are likely facing steep costs. In fact, the Simpson pulp mill, adjacent to the L-P mill, closed down rather than pay an estimated $35 million for plant upgrades to meet the new regulations. A national recent survey of pulp and paper mills showed that 11 closed between 1998 and 1999 and two more are slated to close by 2001. These 13 plants' pulp capacity totals 3.2 million tons/year.[9]

Market Opportunities for TCF Products[10]

As the public has become more aware of the environmental damage imposed by chlorine and chlorine-using process, market interest in chlorine-free products has grown. In fact, one paper supplier is no longer accepting orders for chlorine-free products because their 80,000 ton/year capacity is already allocated.

In response to public interest in chlorine-free products, pulp/paper industry organizations formed and continue supporting the Chlorine Free Products Association (CFPA). To clarify chlorine-free paper product characteristics, CFPA established two designations:

[7] Archie Benton from the Chlorine Free Products Association (ph 847-658-6104, www.chlorinefreeproducts.org)
[8] *Pulp & Paper*, September 1999, pp 73.
[9] *Pulp & Paper*, September 1999, pp 71.
[10] Nearly all content in this section is from Archie Benton at the Chlorine Free Products Association (ph 847-658-6104, www.chlorinefreeproducts.org)

TCF (Totally Chlorine Free)	• No chlorine or chlorine compounds are used in the papermaking process. • The mill does not use old growth forest for any of the virgin pulp. • The mill has no current or pending violations.
PCF (Processed Chlorine Free)	• Products contain at least 30% post-consumer content. • No chlorine or chlorine compounds are used in the papermaking process. • The mill does not use old growth forest for any of the virgin pulp. • The mill has no current or pending violations.

In effect, ***the PCF designation requires TCF pulp for 70% of its content***.

Since L-P is the only U.S. TCF pulp supplier and has had limited market success with TCF products, nearly all TCF pulp is imported from Scandinavia. In fact, one Scandinavian mill increased TCF production capacity twice, from 250,000 tons/year to 550,000 and then to 880,000 tons/year.

Many local and state governmental agencies require the use of recycled paper, and a growing number are requiring PCF paper. The list of organizations requiring PCF paper includes:

- State of Vermont
- City of Chicago
- Cook County (Chicago area)
- City and County of San Francisco
- City of Oakland

Interestingly, Chicago and Cook County are willing to pay up to 15% more for PCF paper.

However, since many paper distributors are unaware of PCF product availability and most governmental directives for PCF products allow use of non-PCF products if PCF is unavailable. Thus, while isolated market niches are increasing the demand for PCF and TCF products, the industry is not yet geared up to adequately meet the market need.

L-P Market Position

While L-P is the sole U.S. TCF pulp supplier, it has not yet capitalized on the market opportunity this unique product offers because of several reasons:

- Historically L-P has shipped about 95% of their product to Pacific Rim countries where pulp buyers prefer unbleached pulp to bleached pulp.
- L-P's TCF process costs more to operate than does the unbleached process. Business economics dictates producing and selling the higher-profit unbleached product.
- L-P has had little opportunity to pursue selling TCF products at a premium compared with chlorine-bleached products. Management changes and the expected sale of the Samoa pulp plant in early 2000 will likely limit L-P's marketing efforts until later in 2000.

L-P's Next Step—CC-TCF Process Upgrades

To improve the CC-TCF process efficiency, L-P has designed and obtained permits to install a $6 million upgrade. The project will include completing the following four steps:

1. Oxygen Delignification Retrofit

   L-P proposes to convert the existing single-stage oxygen delignification system to a two-stage oxygen delignification unit. The new system includes an oxygen reactor with approximately 20 minutes retention time that will provide additional delignification prior to the existing oxygen reactor, which has a 60-minute retention time. This additional reactor is expected to increase the degree of delignification achieved from the current 48% to approximately 65%.

2. New Pulp Presses

   Two new pulp wash presses will improve the washing capacity of the existing fiberline by pressing the pulp between two large steel rolls to remove most of the water from the pulp mat. The washer's filtrate can then be reused in previous wash stages. The amount of lignin removed from the pulp by the wash press is significantly greater than that removed by the existing vacuum type washers. The increased lignin removal will improve the performance of the oxygen delignification stage and bleaching process. Additionally, the wash presses improve the ability to recycle the lignin-containing filtrates, thus reducing the discharge of pollutants to the sewer system.

3. Pressurized Peroxide Bleaching System

   The pressurized peroxide bleaching system is the largest and most complex component of the CC-TCF upgrade project. The new pressurized peroxide stage uses hydrogen peroxide and oxygen at high temperature and pressure to bleach the pulp. The bleaching function is performed currently with the same chemicals, but at lower temperature and pressure. L-P anticipates that the new pressurized peroxide stage will reduce use of bleaching chemicals by 40%

while improving pulp brightness.

4. Replacement of Bleached Pulp Cleaners

While completing the other plant upgrades, L-P plans to replace the current 35-year-old pulp cleaning system with one of a more modern design. The replacement cleaning system will be more efficient in removing dirt from the pulp and may also include additional processing capability to remove lighter particles such as plastics.

The new project is expected to expand plant production capacity by 20%, bringing it back to pre-TCF levels, as shown in Table 11.

Table 11: Expected Impacts of Closed-Cycle TCF Process Improvements

Characteristic	*Units*	*Pre-TCF 1993*	*TCF 1995*	*TCF benefit*	*CC-TCF 2000*	*CC-TCF benefit vs TCF*	***CC-TCF 2001 est***	***CC-TCF 2001 benefit vs. 2000***	***CC-TCF 2001 benefit vs. TCF***
Pulp production	ADt/ day	630	532	-16%	545	2%	**636**	**17%**	**20%**
Mill process water use*	m^3/ ADt	75	52	31%	42	19%	**22**	**48%**	**58%**
Mill effluent	m^3/ ADt	128	113	12%	100	12%	**71**	**29%**	**37%**
Bleach plant water use	m^3/ ADt	44	22	50%	18	18%	**0.7**	**96%**	**97%**
Bleach plant effluent	m^3/ ADt	45	13	71%	9	31%	**7.6**	**16%**	**42%**
Bleach plant steam	GJ/ ADt	2.97	2.47	17%	1.42	43%	**1.42**	**0%**	**43%**
Mill electricity use**	kWh/ ADt	861	909	-6%	909	0%	**916**	**-1%**	**-1%**

* Excludes 8.6 mgd of cooling water and non-contact process water.
** 90-95% from on-site cogeneration plant.

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8. Potential California Applications

Best Applications

As demonstrated at the L-P installation, the best sites for the CC-TCF process are facilities that have completed some modernization, such as having single- or double-stage oxygen delignification and an modern recovery boiler. With such high-cost equipment already in place, TCF upgrade costs can be surprisingly small. Further, since EPA's cluster rules are forcing pulp plants to reduce air and water emissions, TCF is a viable alternative. Table 12 summarizes characteristics of good candidate sites for closed-cycle TCF process upgrades.

Table 12: Characteristics of Candidates for Closed-Cycle TCF Process

Characteristic	*Observation*
• Facing a need to reduce and/or improve wastewater discharge and/or air emissions	• EPA's cluster rule is forcing pulp/paper plants to reduce air and water emissions. CC-TCF is an advanced approach to meet the regulations.
• Facing increased water supply costs	• California's water-supply is getting tighter, with higher flows guaranteed for environmental needs (e.g., salmon spawning) reasons and with a quickly growing population. Eventually water prices will increase, making closed-cycle plants more cost-effective.
• Facing increasing wastewater treatment costs from a municipality.	• Some municipalities penalize industrial plants that contribute heavily to their systems.
• Valuable by-products are lost in wastewater streams.	• Reusing wastewater recovers processing chemicals and heat that may be lost.

Candidate Companies

The pulp/paper processing industry is among the largest water users in California. A survey of the largest water users in the state[11] showed that California firms in 130 SIC sectors use about 370,000 million gallons of water annually, with the top 18 sectors using 60% of the total. Pulp mills are the 13th largest user of these top 18 categories, at 3,200 million gallons/year, although they use less than 1% of the state's total.

The 1997 California Business Register database lists all California companies and categorizes them according to business type. Each company listing includes a range of

[11] Tailored Collaboration project between the CEC and EPRI. Preliminary data quoted here.

characteristics, including site contacts and sales volume. A database sort to identify potential pulp/paper sites in California gave 18 sites for the following primary SIC codes:

- 2621, paper mills (12 sites)
- 2631, paperboard mills (6 sites)
- 2611, pulp mills (0 sites)

The results of the database sort are listed in Appendix C: California Pulp/Paper Plants. For each site the following data are included:

- Company name, address, and phone number
- Executive contact and title
- Business description
- Annual sales

* * *

APPENDICES

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Appendix A: Project Participants

Major Vendors

Ahlstrom Machinery Company

Consulting and Design

H.A. Simons, Ltd.
Peter Gleadow

EG&G Dynatrend
L. Russell Freeman

Pacific Northwest Laboratory
Bernard Saffell

Forsgren Associates

University of Idaho
Department of Chemical Engineering
BEL 308
Moscow, Idaho 83843
Lou Edwards
phone: 208-885-6793
jkidd@uidaho.edu

Grants

DOE NICE[3]
California Energy Commission
Administrative Services Division
1516 9th Street
Sacramento CA 95814
Clinton Lowell
ph 916-654-4304

California EPA
Dr. Richard Green

L-P

(Samoa mill phone: 707-443-7550)

Kirk Girard	Environmental Manager, Western Division L-P Corporation
Sandy Neal	Samoa Pulp Mill Manager
Anton Jaegel	Samoa Pulp Mill Environmental Manager
John Nepote	Samoa Mill Technical Superintendent

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Appendix B: Pulp-Production Overview

Wood is a combination of cellulose, the portion that forms pulp, and lignin, a by-product important for energy production at the mill. The pulping operation separates cellulose fibers from the surrounding matrix of lignin. Regardless of other processing which may take place in a pulp or paper mill, the kraft process involves steps which are common to all kraft pulp mills. In particular, chemical recovery of the pulping chemicals is the one feature that makes kraft mills economically viable.

About 120 trucks/day deliver wood chips about the size of a half-dollar to the Samoa pulp mill. Total daily chip usage is about 1000 tons. The chip pile is shown in Figure 9.

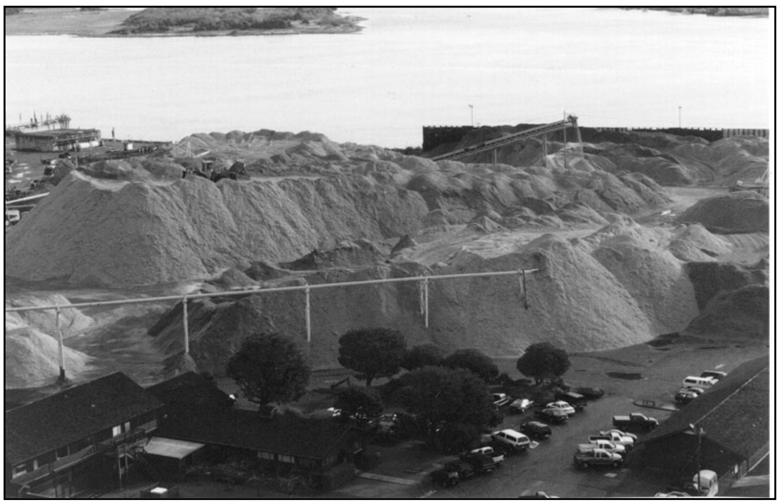


Figure 9: Samoa Plant Wood-Chip Pile

The Samoa pulp mill process is shown schematically in Figure 10 and is briefly discussed below. Although the end-product of the Samoa mill is pulp, this is only an intermediate step in manufacturing paper products, which the mill's customers produce elsewhere.

Digester

Conveyers transport wood chips from storage piles to the digester, which is a large pressure cooker. The digester dissolves the lignin, which holds the cellulose fibers together in the chips, by cooking the chips in a water solution of caustic soda (NaOH) and sodium sulfide (Na_2S). This process destroys some cellulose, while lignin remains. The mixture of digested wood chips (brown stock) and used cooking chemicals (black liquor) are pumped from the digester into a blow tank. Since they exit hot and under pressure, some of the liquid flashes. A heat recovery system captures the heat and pressure released in the blow tank.

Brown Stock Washing

After leaving the blow tank, a series of vacuum filters washes the pulp with recycled water. The first filter uses wash water from the previous (downstream) filter, and so on.

At this point L-P begins the recovery of the spent cooking chemicals by capturing the used wash water (weak black liquor).

Weak black liquor usually exits the washing systems at about 14 to 17% dry solids. The liquor contains too much moisture for it to burn and the heating value is not sufficient to evaporate the inherent moisture. Consequently, some of the water in the weak black liquor must be removed before it can be injected into the recovery boiler for burning. The liquor cycle is described later.

To remove impurities remaining from the digester the pulp is either washed further in more vacuum filters (unbleached pulp production) or whitened using two oxidation processes in series (bleached pulp production). During bleached pulp production the first oxidation process is oxygen delignification and the second is bleaching. Both perform oxidation reactions, but each uses a different method.

Oxygen Delignification

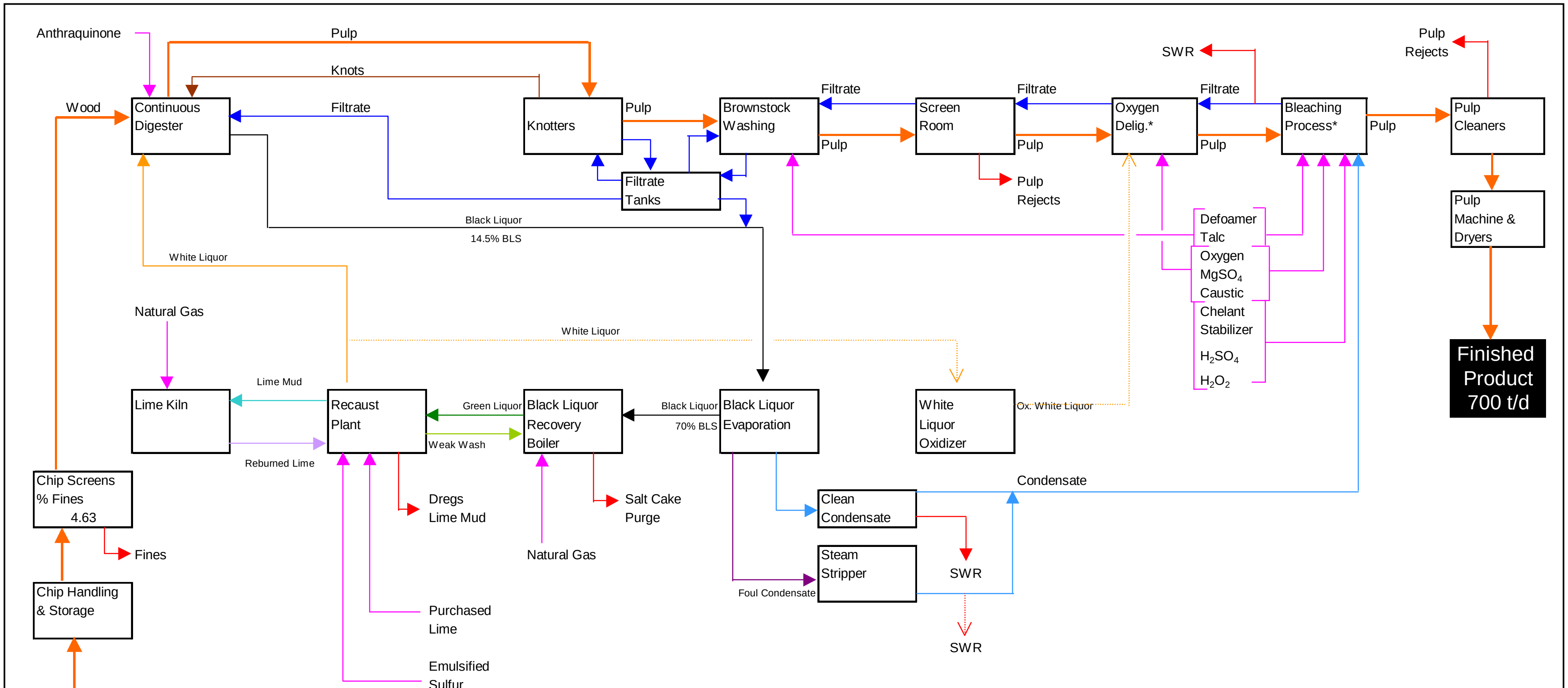
The oxygen delignification process blends the brown stock with a caustic soda solution and oxygenates the mixture in an elevated pressure and temperature environment. The process is more of an extended cooking operation than a bleaching phase. The reactants decompose some of the lignin residual, which is subsequently captured in a countercurrent washing process. The brown stock becomes somewhat brighter in color because the process removes lignins.

The pulp is then washed in two sets of washers. The water applied to the second post-oxygen washer is actually the wastewater generated by the bleaching process discussed below. The water is then used on the first post-oxygen washer and then becomes the wash water applied to the final brown stock washer. This counter current washing results in maximum chemical recovery and minimum loss of lignins to the environment.

Oxygen delignification is a key component in producing totally chlorine free (TCF) pulp. L-P installed this unit in 1989.

Bleaching

The somewhat whitened brown stock is then bleached in a TCF bleach plant. The pulp is bleached in five stages with various combinations of oxygen, hydrogen peroxide, and sodium hydroxide. One or two chelation stages are used in combination with the peroxide bleaching stages to remove low levels of transition metals in the pulp, such as manganese and iron, that may interfere with peroxide bleaching. Under controlled conditions, this technique selectively attacks the remaining lignin without noticeably degrading the cellulose fibers.



* Note: During unbleached pulp production, the oxygen delignification system and bleaching process are bypassed. Typically, pulp washers normally associated with these processes will be used to further cleanse the unbleached pulp.

Figure 10: Pulp Plant Schematic

The main feature of TCF bleaching is that no chlorine, chlorine dioxide, or other chlorinated species are used in the process. *Without bleach in the wastewater, most of the wastewater can be recycled through the oxygen delignification system and the brown stock washers to the digester*. Ultimately, the wastewater components become part of the black liquor recovery cycle and incinerated in the recovery boiler.

Pulp Machine

A series of rollers and presses processes whitened pulp from the bleaching process or unbleached pulp from the pulp washers into pulp stock is formed into a continuous sheet, as shown in . The pulp sheet then enters a drying section where the pulp fibers begin to bond together as steam-heated rollers compress the sheet. The dry pulp sheet is then cut and baled for shipment.

Figure 11: Pulp Sheet

Liquor Cycle—Multiple Effect Evaporators and Concentrator

Weak liquor leaving the brown stock washers is about 85% water. A high-solids concentrator concentrates the liquor to concentrations that can be fired economically in the recovery boiler installed in the mid 1990s. This concentration process delivers 70% solids black liquor to the recovery boiler.

Liquor Cycle—Steam Stripping

In the digester caustic soda reacts with some of the resins in the wood and produces chemicals in the same family as common house-hold soap. Turpentine, methanol and several other liquid hydrocarbon compounds also exist in black liquor. L-P operates a steam stripping system to remove these substances from the condensates, allowing the water to be reused. The products removed by steam stripping are incinerated. The steam stripper was a key component in developing the TCF process. L-P installed the unit in 1992.

Liquor Cycle—Recovery Boiler

The recovery boiler is the first major step in regenerating the cooking liquor used in the digesting phase. This concentrated black liquor is sprayed into the recovery furnace and the organic components burn. The heat produces steam, which is used to produce electricity in a 20 MW steam turbine. Finally, the steam is used throughout the process. The inorganics, remnants of the original cooking liquor, melt and chemically react. These molten chemicals or "smelt" then pour out of the bottom of the recovery furnace where they are mixed with water or "weak wash" in the dissolving tank. The resulting solution is green in color and consequently is given the name "green liquor." The green liquor is pumped out of the dissolving tank to the causticizing area for further processing.

The recovery boiler was another key component in developing the TCF process. L-P installed the unit in 1989.

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Appendix C: California Pulp/Paper Plants

Book Covers Inc
935 E 59th St
Los Angeles, CA 90001-1085
Phone: 213-232-1108
Sales Range: $10 to $24.9 Million
Fiber products for the book, game, looseleaf and printing industries; grape packaging

California Paperboard Corp
PO Box 58044
Santa Clara, CA 95052-8044
Phone: 408-727-7377
James Hoover, President
Sales Range:
Manufactures paperboard and chip board

Clearprint Paper Co Inc
1482 67th St
Emeryville, CA 94608-1081
Phone: 510-652-4762
Sales Range: $10 to $24.9 Million
Engineering, drafting and designing papers

Crown Vantage
300 Lakeside Dr
Oakland, CA 94612-3524
Phone: 510-874-3400
Ernest Leopold, Chairman & CEO
Sales Range: Over $500 Million
Manufactures paper and paper products--printing publishing and converting to food and retail packaging

Fox River Paper Co
942 S Stockton Ave
Ripon, CA 95366-2784
Phone: 209-599-4241
Sales Range: Over $500 Million
Manufactures printing, writing and specialty papers

Jefferson Smurfit Corp
2600 de La Cruz Blvd
Santa Clara, CA 95050-2618
Phone: 408-496-5118
Sales Range: Over $500 Million
Manufactures paper from recycled newspapers

Jefferson Smurfit Corporation
PO Box 58832
Los Angeles, CA 90058-0832
Phone: 213-583-3421
Sales Range: Over $500 Million
Manufactures medium recycled corrugation from 100% recycled fibre

JM Paperboard Company
170 S Maple Ave
S San Francisco, CA 94080-6302
Phone: 415-589-3757
Michael J O'Reilly, Owner
Sales Range: Under $1 Million
Manufactures paperboard products

Kimberly-Clark Corp
2001 E Orangethorpe Ave
Fullerton, CA 92831-5326
Phone: 714-773-7500
Sales Range: Over $500 Million
Manufactures wide range of products for personal, business and industrial uses--facial and bathroom tissue, diapers, industrial wipes; classic, premium business and correspondence papers

Paper Pak Products Inc
PO Box 1060
La Verne, CA 91750-0960
Phone: 909-392-1200
William Griff Hopkins, President
Sales Range: $100 to $499 Million
Manufactures tissue paper, hospital underpads, OB pads and adult briefs

Play Rite Music Rolls
401 S Broadway St
Turlock, CA 95380-5416
Phone: 209-667-1996
John Malone, President
Sales Range: Under $1 Million
Manufactures and sells music paper rolls

Procter & Gamble/Paper Products
800 N Rice Ave
Oxnard, CA 93030-8910
Phone: 805-485-8871
Sales Range: Over $500 Million
Manufactures consumer paper products under the Charmin and Bounty brand names

R & R Manufacturers
4020 Fabian
Palo Alto, CA 94303
Phone: 415-493-1391
Ramon Chavez, Co-Owner
Sales Range: Under $1 Million
Manufactures paper and plastic products

Simpson Paper Company
100 Erie St
Pomona, CA 91768-3342
Phone: 909-622-1321
Sales Range: Over $500 Million
Manufactures printing, writing and specialty papers

Simpson Paper Company
PO Box 637
Anderson, CA 96007-0637
Phone: 916-365-2711
Sales Range: Over $500 Million
Manufactures printing, writing and specialty papers

Smurfit Newsprint Corp/Calif Inc
PO Box 2364
Pomona, CA 91769-2364
Phone: 909-623-6601
Sales Range: Over $500 Million
Manufactures newsprint from 100% recycled paper

Specialty Paper Mills
PO Box 3188
Santa Fe Springs, CA 90670-0188
Phone: 562-692-8737
John A Gabriel, President
Sales Range: $10 to $24.9 Million
Manufactures medium corrugated paperboard

Willamette/Pulp & Paper Div
PO Box 519
Port Hueneme, CA 93044-0519
Phone: 805-986-3881
Sales Range: Over $500 Million
Manufactures liner board and bag paper